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Report No. FAA-RD-80-87

PRELIMINARY TEST PLANS OF ATC CONCEPTS FOR LONGER TERM IMPROVEMENT

HELICOPTER OPERATIONS DEVELOPMENT PROGRAM

May 1980

Task Report

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U.S. DEPARTMENT OF TRANSPORTATION

FEDERAL AVIATION ADMINISTRATION

Systems Research & Development Service

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16. Abstract
Test and simulation planning is documented for longer-term improvements in helicopter ATC concepts, which are classified into the following categories:

1. Offshore Route Structure in the Gulf of Mexico,
2. Secondary Radar,
3. Analysis of Navigation Errors in the Gulf,
4. Offshore Surveillance and Communications to 300 NM Range,
5. Real-Time Reporting of Aircraft-Derived Position,
6. VHF Communications Study in the CONUS,
7. ATC Implications of Alternate Airports for Helicopters, and
8. Wake Vortex Separation.

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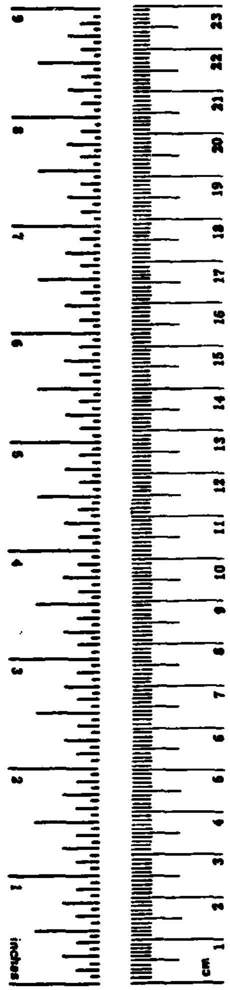
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

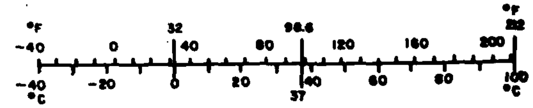
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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I wish to express my sincerest gratitude to all the above stated organizations and look forward to continued association with them during my continued involvement in the helicopter program.

Raymond J. Hilton
ATC Helicopter Program Mgr.

PRELIMINARY TEST PLANS OF ATC CONCEPTS
FOR LONGER TERM IMPROVEMENT
(Helicopter Operations Development Program)

INTRODUCTION

In an earlier companion document (Report No. FAA-RD-80-XXX) recommendations were made concerning simulations that could be completed in the short term on new helicopter ATC concepts. This document also addresses new ATC concepts but considers those that would be applicable to helicopter operations in the longer term. In general, the added time required to validate the concepts stems from the complexity and scope of the simulations and tests that must be performed.

A considerable portion of the work completed to date on helicopter ATC has been focussed on offshore operations in the Gulf of Mexico. As a consequence a number of the longer term ATC concepts discussed herein are discussed in relation to the Gulf. Nevertheless, all are applicable to offshore operations in any geographical area and most are also applicable to remote area operations over land. In addition, several of the concepts are not related to offshore operations and are applicable anywhere. The list of concepts addressed is as follows:

1. Offshore Route Structure in the Gulf of Mexico
2. Secondary Radar
3. Analysis of Navigation Errors in the Gulf
4. Offshore Surveillance to 300 NM Range
5. Real-Time Reporting of Aircraft-Derived Position
6. Communications Study of VOR/DME in the CONUS
7. ATC Implications of Alternate Airports for Helicopters
8. Wake Vortex Separation

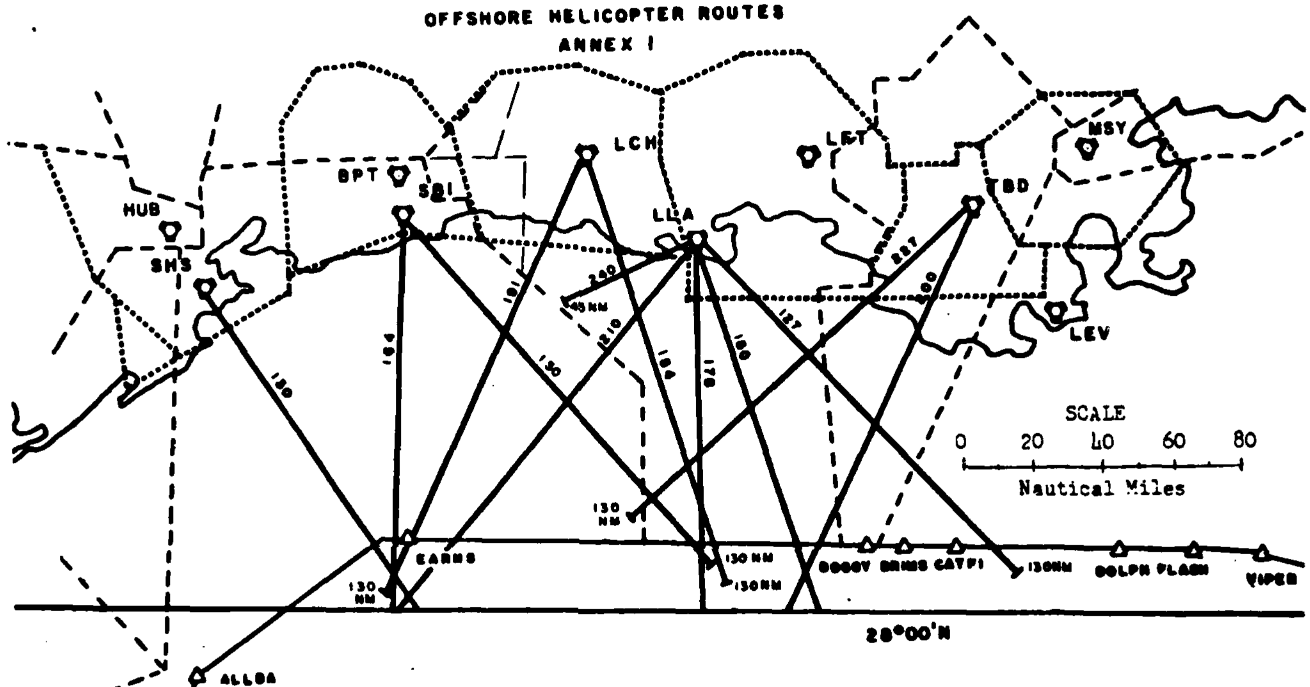
1. Offshore Route Structure in the Gulf of Mexico

In spite of the lack of obstructions, and the almost homogeneous coverage of the navigation infrastructure over the Gulf of Mexico, all IFR helicopter flying over this area is based on the use of standard routes; and prospective operators are flight checked and approved for individual standard routes only. The number of routes has deliberately been kept at a minimum to reduce the number of conflict points in an ATC system which is without ATC surveillance over most of the offshore helicopter operating area.

The present route structure, which is shown in Figure 1, is based on the use of radial courses form the FAA VOR/DME facilities, out to 40 miles from the VOR. Beyond these points, the radial routes are extended via Loran-C waypoints.

Routes are laid out to serve the main offshore platforms from various heliports on shore. Most radial routes come within 20 NM of the destination offshore platforms. At predefined and designated points within 20 miles of the destination, outbound pilots leave the radial routes on a direct path to the destination platform as shown in Figure 2. Return flights follow the same indirect routes in the opposite direction. From time to time, it can be expected that the main routes will be shifted to meet changes in the traffic demand as new oil and gas fields are opened up, or new helicopter operations bases are developed on shore.

With the advent of ATC surveillance over this area, there would appear to be no particular reason why certain flights could not follow direct routes as shown in Figure 3 to save flight time and fuel, and also to



INBOUND CLEARANCE LIMITS

Houston	Beaumont	Lake Charles	Lafayette	New Orleans
SHS 130/20	SBI 164/10	LCH 154/35	LLA 240/20	TBD 200/23
	SBI 130/10	LCH 191/35	LLA 210/26	TBD 227/35
			LLA 178/21	
			LLA 150/22	
			LLA 127/30	

MEA all routes 1500
MAA all routes 10,000

Figure 1. Offshore Helicopter Routes in the Houston Area

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3/20/80

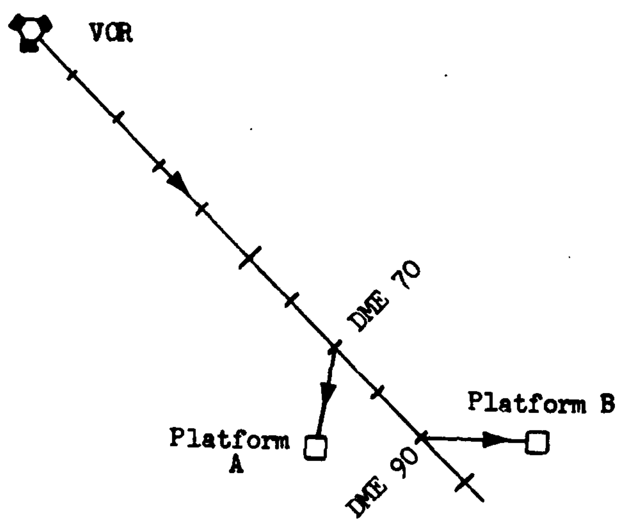


Figure 2. Typical radial route plus branches or spurs to individual platforms.

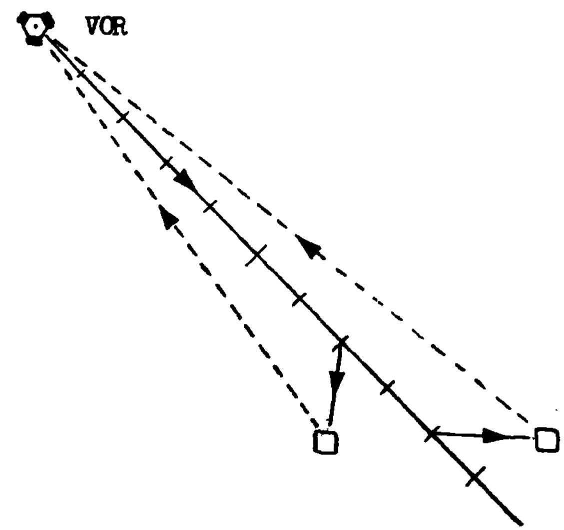


Figure 3. Direct Return Routes to Save Fuel

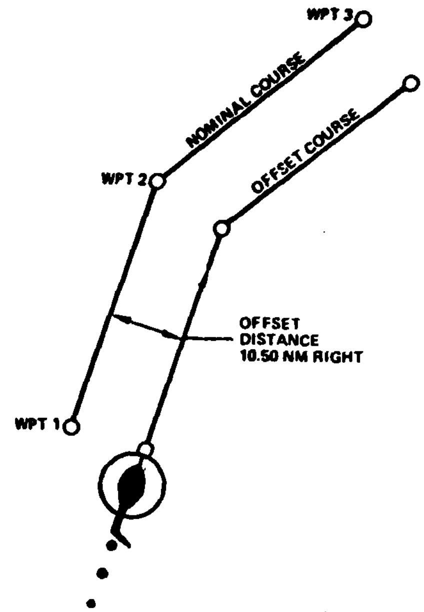
provide more lateral separation from traffic on the radial routes, although in most cases, opposite-direction traffic would still require altitude separation from each other.

If the future IFR traffic density reaches a point where delays become a problem, dual one-way parallel routes will be able to accommodate more IFR aircraft safely in the relatively few helicopter altitude levels available. The TDL-711 Loran-C avionics already has the capability to fly offset routes as shown in Figure 4 without changing the waypoint settings. For example, if it is established someday that 12 nm lateral separation is a safe minimum for aircraft using LOFF, then a dual parallel route could be set up for opposite-direction traffic, offset 12 nm from the original route.

Having opposite direction traffic on dual airways at the same altitude level will be advantageous at busy route intersections where such routes can be crossed by other dual routes at an adjacent altitude level. As shown in Figure 5,this could simplify ATC operations by eliminating traffic conflictions caused by opposite-direction or crossing traffic.

From time to time, there is already a need for direct random routes, for Medevac, storm evacuation, or Coast Guard operations. Also the growing need for all-weather helicopter operations may generate the need for multi-segment IFR hops from platform to platform. If this traffic is to be controlled by ATC, the controller will need to be able to call up these random routes temporarily on the ATC display, either automatically from the flight plan, or by manual entry. The LOFF display will have the capability to call up and erase such routes, on an as-needed basis. Having such a capability in future ATC computer software could be a key factor in the ultimate acceptance of area navigation in other parts of the ATC system.

Figure 4. Offset Route Capability of TDL-711. Pilot enters offset distance (10.50 NM Right) without changing waypoint setting.



It is recommended that an analysis and ATC simulation be conducted by the FAA Technical Center to determine at what level of traffic density a single-route system, and a dual route system, experience unacceptable delays:

(a) Under procedural control;

(b) Under radar-type control where a vectoring capability is assumed, using horizontal separation standards of 5 nm and 10 nm.

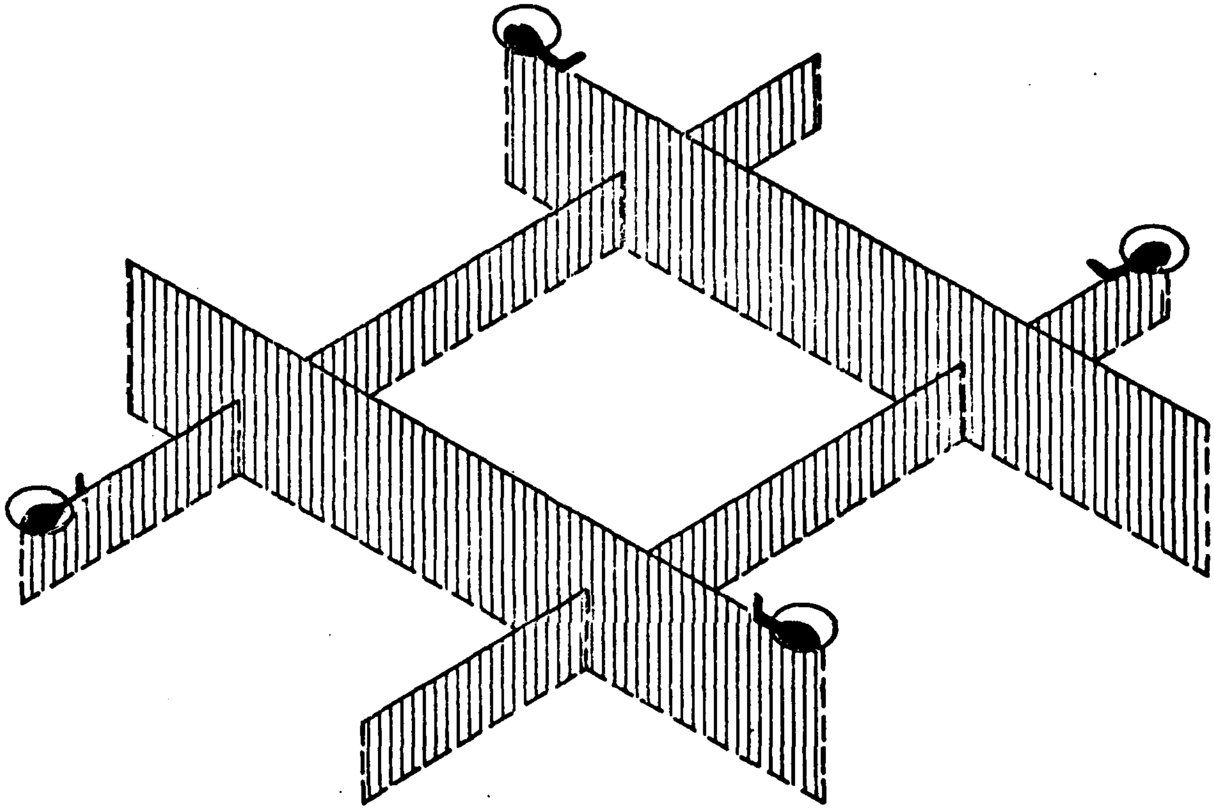


Figure 5. Concept of Alternating Opposite-Direction Routes at Same Altitudes Crossed by Alternating Opposite-Direction Routes at Adjacent Altitude

2. Secondary Radar

(a) Background

The most desirable form of surveillance for the control of IFR traffic in the Gulf of Mexico would be by secondary radar. This would permit control to be conducted under the same separation standards as in the NAS. Up to the present time, this has not been seriously considered for several reasons:

(1) There has not been sufficient IFR traffic to warrant such service.

(2) The ATCRBS interrogators have been relatively expensive ($\approx$\$1.5M per unit) and have used large antennas.

(3) It would be difficult and not practically feasible to consider such coverage for the entire expanse of the Gulf where oil operations are being conducted or planned.

(4) The relatively expensive communications outlets to support the secondary radar units are not available.

Now the situation is changing considerably.

(1) The IFR traffic is increasing rapidly.

(2) There are lower cost, smaller sized secondary radar units available that have been developed by the Army (See par. (2) below).

(3) It appears feasible to consider radar service in selected areas where helicopter traffic is heavy.

(4) Plans have been made to install five RCAG units in the Gulf so that helicopters would have direct communications with an ATC Center. The first of these will be installed in 1980.

In view of these changed conditions, it would appear desirable to install an experimental radar unit in the Gulf to evaluate the desirability of using such service more extensively.

(b) Very Light Weight Air Traffic Management Equipment (VLATME)

The Army has developed the VLATME secondary radar as a means of obtaining a light weight, inexpensive unit that can support tactical helicopter operations. It is being tested in three versions, i.e.: a hand held unit that can work with two aircraft, a TV display unit that can work with 10 aircraft, and a larger plasma display system than can work with approximately 100 aircraft.

The larger unit is the one that would be most suitable for the experiment of a surveillance system in the Gulf. While larger than the other two units, it is still small when compared to current ATCRBS interrogators. Its physical size is 5 feet in height and 18 inches in diameter. This is small enough to be considered for installation on an oil platform.

The VLATME is compatible with ATCRBS Modes 1, 2 and 3 and hence, no modification would be required to helicopters equipped with a beacon. Its azimuth accuracy is 3/4 of a degree and its range is about 50 NM at a helicopter height of 1,000 feet.

The cost of a present unit as configured for the Army is $150K. The unit is made in accordance with commercial standards and would therefore, not be suitable for a salt water environment.

(c) Recommended Test Program

The initial RCAG unit to be installed in the Gulf will be at Vermilion 245. This would be an ideal location for the VLATME if a suitable site can be located on that platform and if the additional communications channels to support the radar and relay the radar data to the Houston Center could be provided.

Figure 6 is an approximate drawing showing the range of the VLATME (i.e., 50 NM) with helicopters at a height of 1,000 feet. It can be seen that coverage is provided almost to the coastline South of Intercoastal City. At higher IFR altitudes, the coverage would be only slightly greater with the current power capability of the VLATME. To the West, the coverage extends over much of the West Cameron area and to the East, Eugene Island. To the South, the coverage would go almost to the current limit of drilling operations.

This chart indicates that there would be virtually complete surveillance coverage along several of the high density established IFR routes emanating from the Intercoastal City area. Accordingly, all parameters would be satisfied to permit the Houston Center to provide separation standards for IFR flights in the radar coverage area that are essentially the same as for the NAS. There would be radar service and there would be communications.

A corollary benefit of this experiment would be to evaluate the accuracy of the LOFF system and establish techniques and procedures that would permit

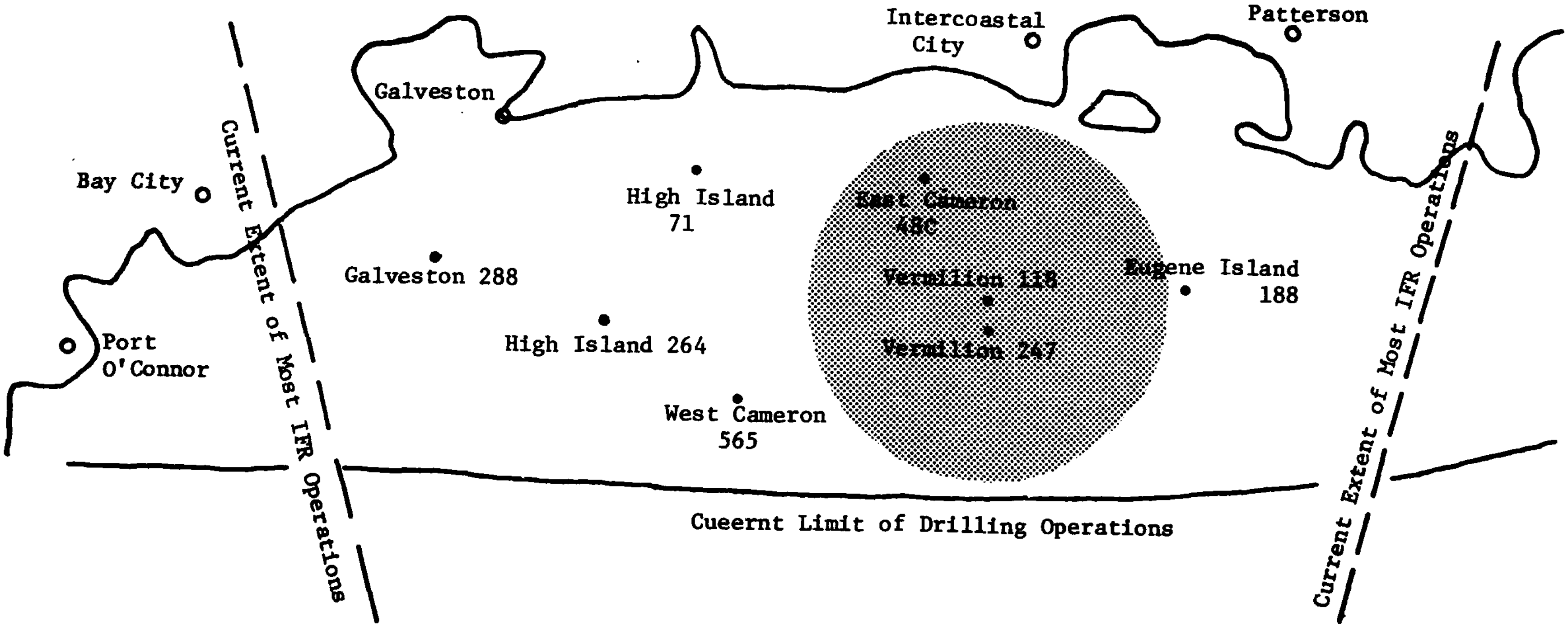


Figure 6. VLATME Coverage With Helicopter at 1,000 Feet

compatible operations in the Gulf between LOFF and the radar surveillance system.

In planning the VLATME hardware procurement for the Gulf of Mexico experiment, it would be desirable to use specifications (e.g., AN/TRX-42 functional specifications, type 1,2 or 3) that have been developed for (and proven successful in) salt water environments. It would also be desirable to increase the power and make other modifications needed to extend the range to 60 or 70 miles.

3. Analysis of Navigation Errors in the Gulf

(a) Background

Control of IFR helicopter traffic in the Gulf of Mexico by the Houston ATC Center is done by procedural control. This requires large separation standards between helicopters -- for example, the IFR routes beyond VOR/DME coverage are presently ± 50 NM in width.

There are two basic reasons why procedural control is needed. First, there is no independent radar surveillance system such as is used generally in the NAS. Thus, the center has no means of continuously knowing the real time progress and position of the helicopters. Second, the basic navigation system in the Gulf (i.e., Loran-C) is not fully certified and hence, reasonably narrow route widths have not been established.

The projections of IFR helicopter traffic indicate that within a few years procedural control will not be efficient enough to handle the volumes of traffic expected. Accordingly, actions are needed to provide both surveillance and approved navigation service in the near future.

This discussion deals with the Loran-C navigation service -- the question of surveillance systems is addressed in other documents.

(b) Loran-C Accuracy Parameters

The width of the Federal Airways in the NAS (i.e., ± 4 NM for low alitude "Victor" airways) is based on the combined errors that are possible in (a) the ground VOR/DME equipment, (b) the airborne VOR/DME equipment, and (c) the flight technical error (FTE). Advisory Circular 90-45A allocates the errors as follows:

Ground VOR Station Error (cross track) (51 NM)	±1.7 NM
Airborne VOR equipment Error (cross track) (51 NM)	± 2.7 NM
Pilotage Error (cross track) (51 NM)	±2.2 NM
Total Error (RSS)	±3.88 NM

The VOR's are always sited close enough to each other (i.e. $\leq$ 102 NM) so that the error allocated to the ground station does not exceed ±1.7 NM at the maximum specified VOR range of 51 NM. Since the displacement associated with azimuth errors of VOR increase directly with range, the use of VOR service beyond 51 NM would require wider airway widths. With these parameters, the airways can be standarized to the ±4 NM width throughout the low altitude NAS structure.

With an area system such as Loran-C, the primary errors are not directly related to the distance from the ground station. Instead, they depend mainly on the crossing angles of the two lines of position obtained from any three station nets. (See Figure 7). The greatest accuracy is achieved when the lines are perpendicular and the system error increases as the crossing angles become smaller. Thus there is a continuously changing error in the Loran-C system as an aircraft moves throughout the navigation service area.

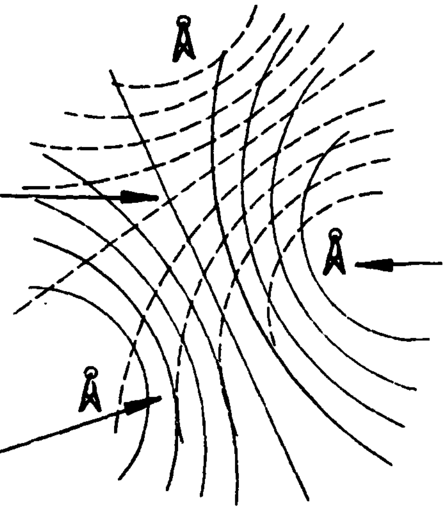


Figure 7. Loran System Accuracy

The problem to be addressed is to identify the zones in the Gulf Coast Loran-C chain where the accuracies are adequate to substantiate certain IFR route widths. After examining total system accuracy contours, it may turn out that $\pm$ 4 NM either is or is not an optimum width. The selection of route widths may also depend on where the highest traffic densities are located and in fact, what the total volume of traffic is. It is also possible that a selection of two or more route widths may be desirable. A narrow route width might be desirable in the zones where Loran-C has its greatest accuracy; a wider width might be desirable elsewhere.

Another element of this investigation is the failure modes of the Loran-C ground stations. If any one of the three stations in the Gulf net becomes inoperative, that station is substituted by the Jupiter, Florida Loran station. As a result, there are three additional geometric structures of Loran-C service in the Gulf. For each of these, accuracy contours must be developed which can later be translated into routes widths for the control

and separation of traffic during those failure modes.

(c) Analysis of Loran-C Accuracy

It is likely that the Coast Guard has already performed much of the analysis of Loran system accuracy in the Gulf. It is also possible that zones have been identified where the accuracies are adequate for airway widths of ± 4 NM in accordance with AC 90-45A. (Note: Errors would need to be allocated in a similar manner as has been done for VOR -- which is illustrated in paragraph (2) above). If all of these accuracy studies have not been performed, they should be. It is a straightforward problem that, apart from any prerequisite flight tests, can be solved in a reasonably short time.

Once these accuracies are known, a further study can be performed to determine recommended IFR route widths for various areas where helicopters operate in the Gulf. The recommended route widths for the emergency modes should also be determined.

(d) Flight Test

While most of the work described above can be accomplished by paper analysis, there is a need to confirm the validity of the results by flight check. This should be done for both the normal mode of operation of the Gulf Loran chain, and also for the three back up emergency conditions when one of the three Loran stations becomes inoperative. It appears that NAFEC is the most logical organization to plan and conduct this flight inspection.

4. Offshore Surveillance and Communications to 300 Miles in the Gulf of Mexico

(a) Background

In the Gulf of Mexico the present southern limit of drilling operations is about 28° North latitude which goes to about 110 NM south of the U.S. coast. For the future, however, there are plans to conduct drilling as far as 300 NM offshore. This raises several questions with respect to how air traffic control can be handled for IFR operations. Mainly, the questions concern how navigation, surveillance and communications services will be provided.

(b) Navigation, Surveillance and Communications

The coverage of the two main navigation systems in the Gulf (i.e., Loran-C and VLF/OMEGA) includes all of the area to the 300-mile limit. Accordingly, navigation is not a major problem. However, the only present communications and surveillance systems that are extensively used are in line-of-sight radio frequencies and hence the services are very limited.

The main options for providing improved surveillance would be:

- Secondary radar
- Real-Time relay of aircraft-derived position information to the ATC Center.
- Over-the-horizon radar
- Satellite radar

The main options for providing communications are:

- VHF
- HF
- VHF tropospheric scatter
- Satellite communications

(1) Secondary Radar and Associated Communications

As indicated in par 1b above, the Army has developed a new light-weight secondary radar (i.e., VLATME, Very Light Weight Air Traffic Management Equipment) that shows excellent potential for use in offshore helicopter operations such as in the Gulf of Mexico.

Figure 8 is a map of the Gulf that illustrates the coverage of VLATME and where an installation could be made to test the system at ranges out to 300 NM. The parallel of latitude at 25° North is also shown on the map and indicates the approximate limit of 300 NM South of the U.S. coast. The circles are 50 NM in radius and represent the present maximum range of VLATME which can be obtained at helicopter altitudes of 1,000 feet and higher.

The circle to the North shows the coverage of a VLATME installed at Vermillion 245. The circle to the South shows a hypothetical location in which the radar coverage would extend to the 300 NM limit. One important inference that can be made from this map is that the zone of no radar coverage between these two locations is not large. If one assumes a relatively light density of helicopter IFR traffic to the more distant oil platforms, a reasonable case can be made that the radar coverage around the destination would be adequate to support ATC separation services to that area. Another inference is that it would not take many VLATME systems to provide similar coverage to that portion of the Gulf that is West of New Orleans and North of the 25th parallel -- where most oil operations are conducted.

An isolated VLATME is of no use unless communications can be provided that relay the radar data and the air/ground

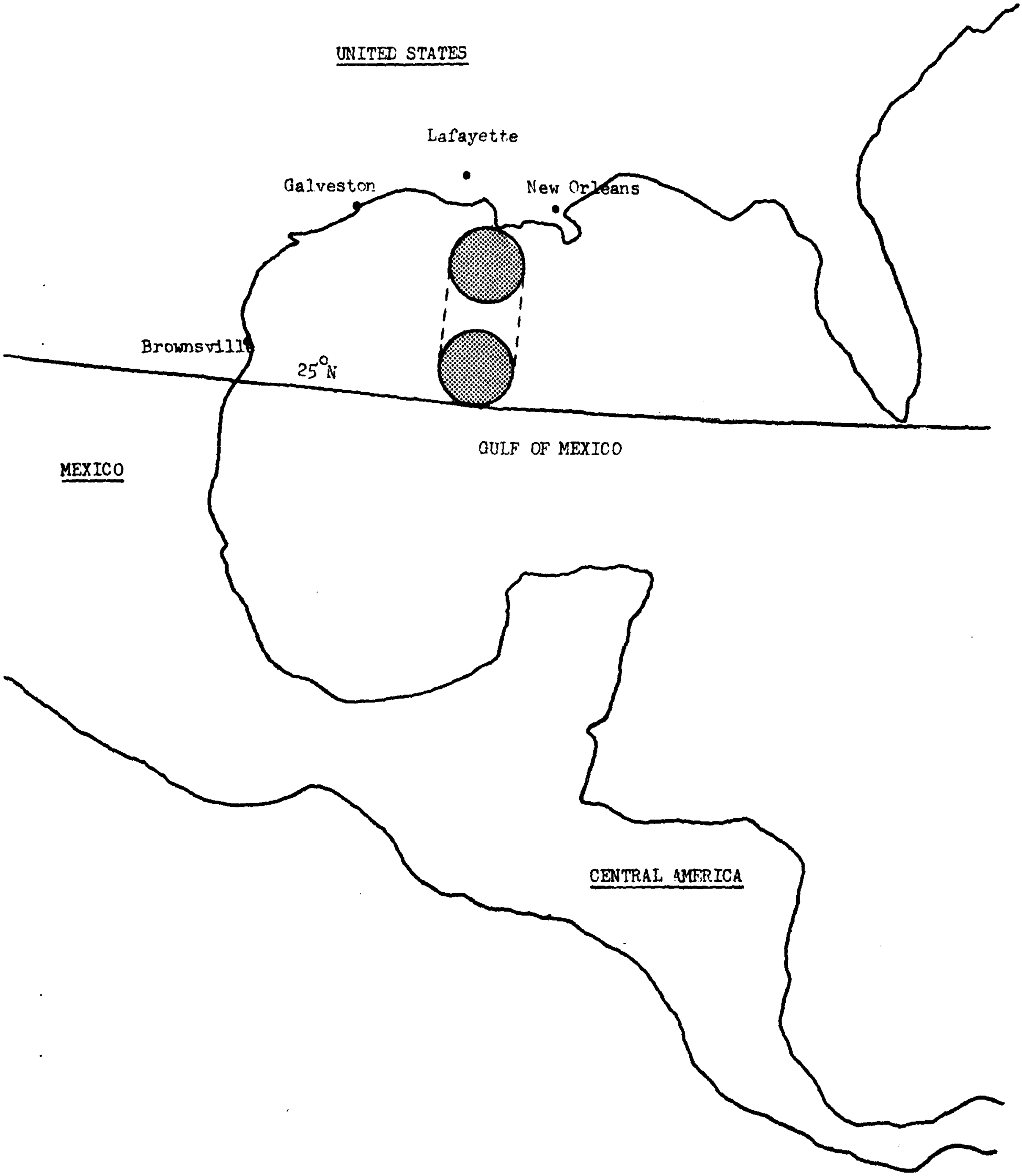


Figure 8. Secondary Radar Coverage.

communications back to the ATC center. As a means of finding the most cost-effective way of doing this, experiments should be conducted with all of the options listed in par (b) above. If the oil companies provide microwave or cable links to the site, then VHF transmissions from the aircraft could be relayed to the center by that means. Also, HF should not be overlooked for the few long-range IFR helicopters that would fly to the distant platforms. HF has been used in the Gulf by helicopters before. While it has appeared to helicopter operators to be less satisfactory than VHF, it can be made to work. Another alternative that appears to be operating satisfactorily in offshore oil operations in the North Sea is tropospheric scatter. The tropospheric scatter communications are used to link the shore station to the oil platform. The helicopter contacts are made with the platform by normal VHF equipment. Finally, a study and test should be made of available satellite communications that would link the distant platform to the ATC center.

(2) Real time relay of aircraft derived position information

At the present time the primary candidate system for relaying position information to the ATC center is LOFF (Loran-C Flight Following). That system is expected to be in operation for experimental purposes by January 1981. Since there is such good Loran-C coverage in the Gulf it provides a natural basis for being used for this corollary purpose. For the more distant future the GPS NAVSTAR system seems very promising. Since it has worldwide coverage it could be used by helicopters in any part of the world (not just the Gulf) where present standard navigation system service (i.e., VOR/DME) is not available.

The communications techniques applicable to support these concepts of relaying position information are identical to those discussed above for the surveillance radars.

(c) Over-the-Horizon and Satellite Radar

In the longer term future it is possible that satellite or over-the-horizon radars will provide the solutions for surveillance for helicopters in the Gulf and other remote areas. An analysis should be performed of the state-of-the-art in these techniques and an assessment made of their projected utility and the time period in which they might be used.

(d) Recommended Test Programs

It is recommended that the following test programs be conducted to pursue the ideas expressed above:

(1) Procure and install a VLATME system in the Gulf. Provide associated communications links to the Houston ATC Center and the VHF or ground communications for contacts with the helicopters.

(2) Perform experiments on alternate communications services to link the VLATME to the ATC center. This should include HF, tropospheric scatter, and Satellite forms of communication.

(3) Perform an analysis of the state-of-the-art of satellite and over-the-horizon radars that would be suitable for surveillance of helicopter traffic in the Gulf.

5. Real-Time Reporting of Aircraft-Derived Position

a. Low Altitude Surveillance

Many helicopters operate beyond or below primary and secondary radar coverage in offshore and remote areas. Without surveillance, ATC must revert to the use of procedural separation standards, which seriously limit IFR traffic capacity through the areas where it must be used.

Although the principle of independence between surveillance and nevigation is desirable full independence is not always achievable due to the cutoff of primary and secondary radar signals beyond the horizon.

One possibility for solving this problem is to use a concept known as navigation-dependent surveillance. In this concept, position data obtained from a navigation system in the aircraft is telemetered to the ATC facility, for processing and presentation on a PPI display. To obtain the most useful display for air traffic control, it would be desirable that such a display be able to integrate inputs from this system with inputs from the primary and secondary radars in areas where the latter are available.

b. LOFF

An experimental Loran-C Offshore Flight Following (LOFF) system is now being developed for the surveillance of offshore helicopter traffic over the Gulf of Mexico. This system will provide an initial look at the capabilities and limitations of navigation-dependent surveillance systems.

The LOFF concept is based on the telemetering of position data obtained from the Loran-C receiver in the aircraft, back to the ATC facility. The digital position messages also will contain the aircraft identification code, together with data regarding the assigned altitude and the operating mode of the Loran receiver. These messages will be decoded and processed by a mini-computer, for presentation on a special alphanumeric/graphics CRT display. The LOFF system concept is shown in Figure 9. The LOFF will be a stand-alone system, not interfaced with the NAS computer in any way; obviously it can be employed only by specially equipped aircraft using data from the Loran-C navigation system.

If the tests indicate that this concept is viable for ATC surveillance, ultimately it will be desirable to extend the concept of navigation-dependent surveillance to other blocks of airspace, such as oceanic and remote areas which cannot be covered technically or economically by primary or secondary radar. In this case it would be desirable to have the capability of accepting position messages from other navigation systems such as Omega/VLF, INS, or GPS, as well. This would include the maximum number of aircraft within surveillance, at the lowest cost to the user (who may already have some other system besides Loran-C), and also would provide the protection of a backup system for any aircraft with more than one system, in case of failure of the primary navigation system.

Tests of the LOFF system make a significant contribution to operational knowledge as to the usefulness and reliability of navigation-dependent surveillance. Some of the factors to be determined during the tests are:

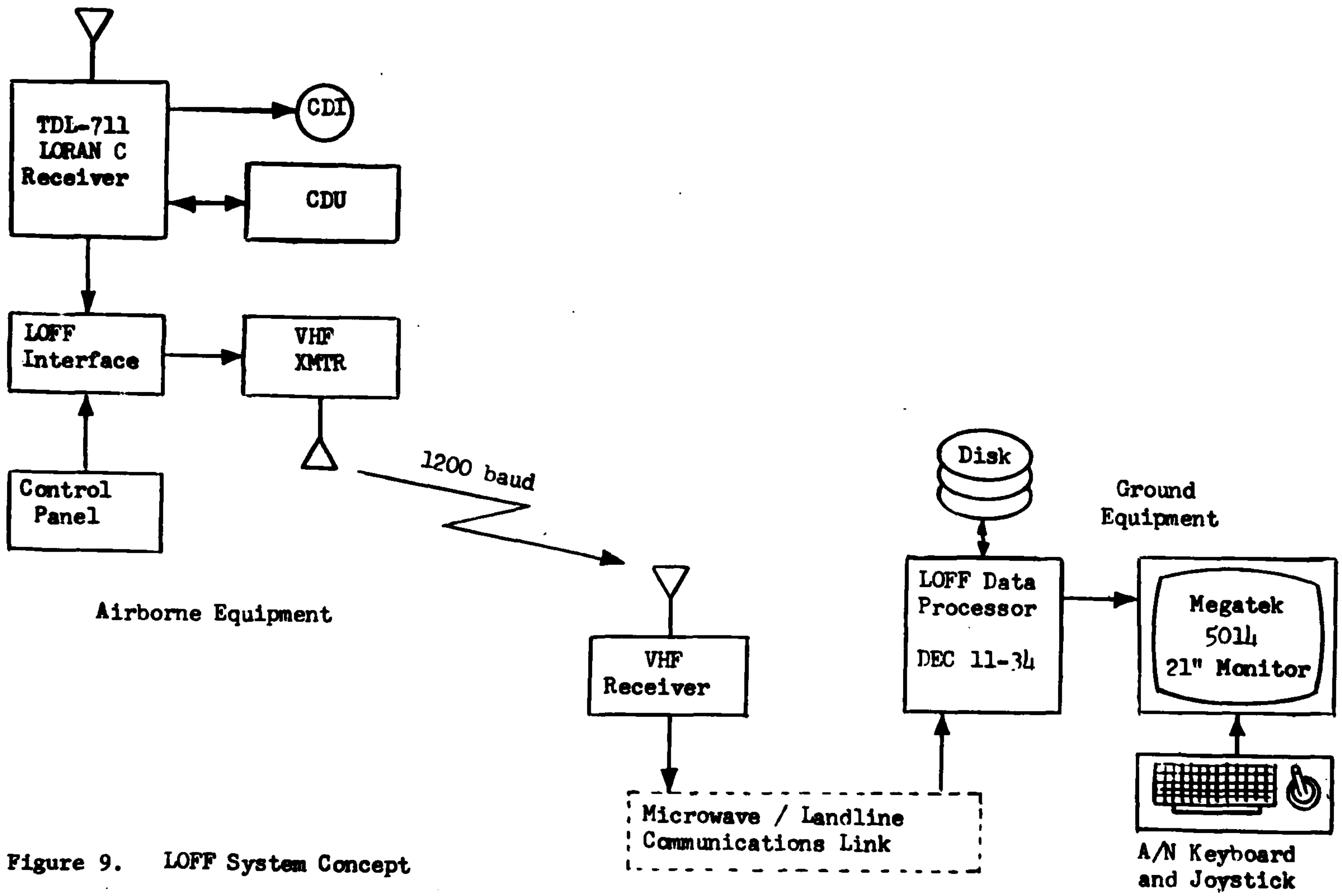


Figure 9. LOFF System Concept

Reliability

Need for backup system

Accuracy of Loran-C System in various areas

Effects of message repetition rate on position accuracy

Need for tracking and coast mode

Effect of communications and data processing on position errors

Effect on pilot workload

Effect on ATC capacity workload, flexibility, and safety

Human factors in controls, displays, and communications

Probable value of concept in other applications.

If tests of LOFF are successful, the next step would be to apply it over a larger area than the Gulf and to other areas such as Appalachia for flight following. It is possible that this step would have to be preceded by the installation of additional remote air/ground VHF communications outlets in order to relay the LOFF messages back to the ATC facility. Further applications of the LOFF system would depend on the outcome of such tests.

Meanwhile, it is recommended that studies begin on the development of an integrated multi-source navigation-dependent surveillance system suitable for oceanic traffic control, as well as the flight following and/or control of offshore helicopters going out to the maximum expected range of 300 NM offshore in certain areas.

This application presents the need for studies and development to obtain the most suitable communication channel for getting the data link messages back to the ATC. The distribution of remote VHF communications

outlets and of microwave relays from platform to platform makes the communications problem comparatively simple in the Gulf area. However, other means will have to be used where there are no intervening platforms and no undersea cables for 200-300 NM of open sea.

The most likely communications candidate is HF, but this is not ideal because of static and because of diurnal skip conditions which make the use of a set of different frequencies (rather than a single frequency) necessary, in order to maintain communication between low altitude aircraft and shore facilities.

The use of satellites for this application is an expensive alternative. With a helicopter this presents a problem of how to overcome rotor modulation.

In 1970 the FAA tested a pictorial display concept in the oceanic portion of the Oakland ARTCC, using a small general-purpose computer to extrapolate aircraft positions on an alphanumeric/graphics display. This project was documented in Reports FAA-RD-71-38, "Evaluation of a Flight Plan Position Information Display for Oceanic Control"; and FAA-RD-71-92, "Experimental Support for Demonstration of an Automated Position Reporting Technique at Oakland, California". The former report discusses hardware, software, and flight plan extrapolation; the latter discusses the communications aspects, including the use of data link. It is recommended that both of these reports be reviewed as background material, before starting the evaluation of any navigation-dependent surveillance system.

c. Multi-Source Navigation-Dependent Surveillance.

It would be desirable for a navigation-dependent surveillance system to be able to integrate inputs from the various navigation

systems (plus primary and secondary radar if available) on a common standard display console. Such a system is shown in Figure 10.

Such integration would introduce the problem of separating aircraft on the basis of positions received from different navigation systems having various amounts of error in various geographical areas. To solve this problem, the ground data processor would have to know the source of the navigation data in use by each aircraft, and the error characteristics of each navigation source. The former information could be included in the flight plan, and in each data message (as presently planned in the LOFF system); the latter could be stored in the computer.

The amount of separation to be applied between aircraft must always exceed the combined position errors which can occur. In this case we would define position error as the difference between the actual geographical position and the displayed position of the aircraft. In a navigation-dependent surveillance system, position error would include navigation error plus any additional errors introduced by communications and processing of the data.

Assuming that the aforementioned information were available, it is possible to conceive of a multi-source navigation-dependent surveillance display as a number of circles of varying radii, in which the center of each circle is the reported position of an aircraft as processed by the computer; and the radius of each circle corresponding to the 2-sigma position error (as defined above), plus 1/2 of the minimum horizontal separation standard (See Figure 11).

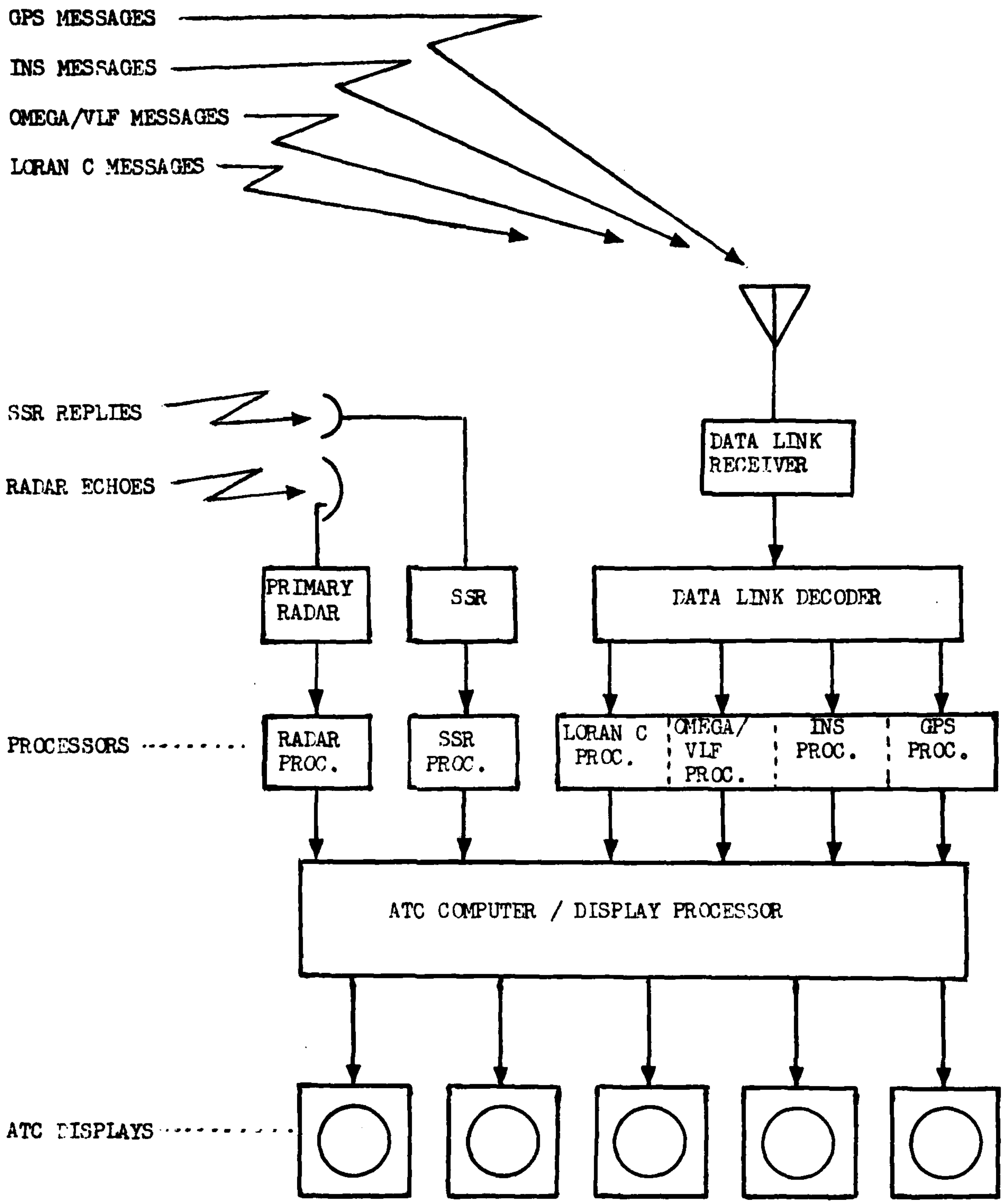


Figure 10. Concept for Integrated Multi-Source Navigation-Dependent Surveillance System

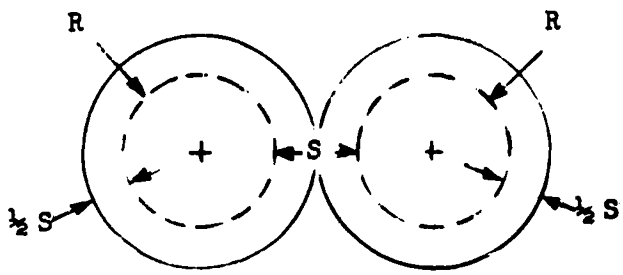


Figure 11. Circular Position/Separation Concept.
Crosses show processed positions.
R= 2 Sigma error, S = separation standard

Separation would be maintained by keeping the (outer) circles from touching each other. It is expected that the circles would be displayed only intermittently as needed for a check by the controller.

If traffic is light, it may be practical to use enough separation between aircraft to compensate for the least accurate navigation system in use. In other words, all the circles would be the same relatively large size. As traffic density increases, however, it would be desirable to take advantage of the increased accuracy of the navigation systems in use by certain aircraft, by being able to decrease the separation between those aircraft accordingly. To do this, the ground data processor would have to know the source of the navigation data in use by each aircraft, and the error characteristics of each navigation source within the particular operating sector. With the appropriate processing, the size of the circles around the aircraft using the more accurate navigation systems would be decreased, and the display would look more like Figure 12.

The conflict prediction system should warn of any impending overlap in the projected areas of the circles of any two aircraft at, or passing through, the same altitude level (See Figure 13).

It is quite possible that after the usable accuracy of each navigation system is established, it may be possible to set up a conservative matrix of separation standards for the various combinations of navigation systems being used for traffic surveillance within a given geographical area. Such a matrix is shown in Table 1. In this matrix, (which is purely hypothetical and is not based on measured accuracies)

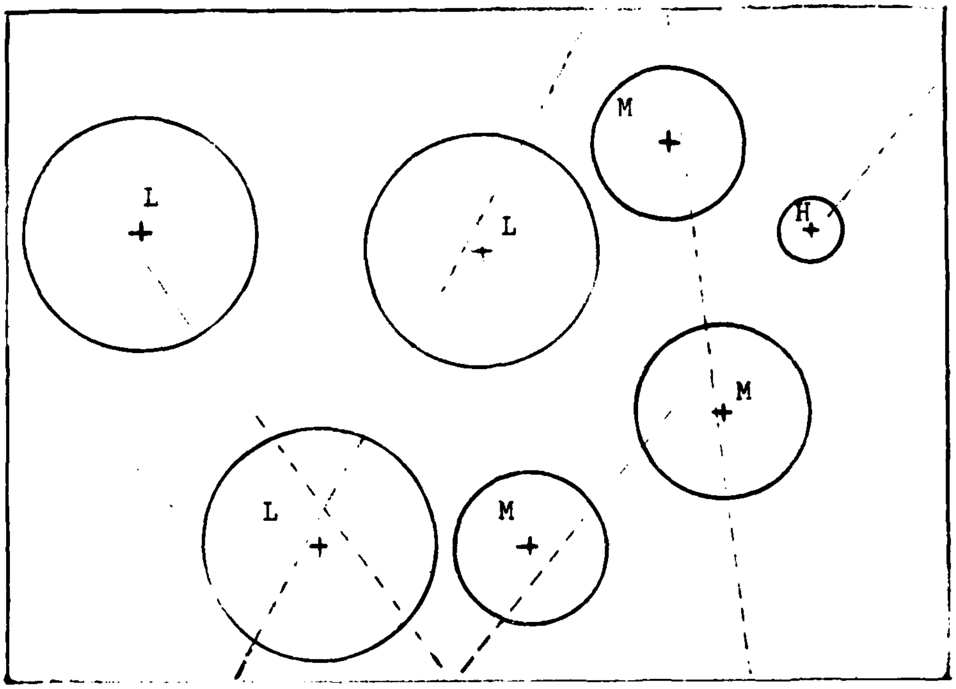


Figure 12. Possible situation display (target tags not shown) for aircraft using (L) low, (M) medium, and (H) high accuracy navigation systems in multi-source navigation-dependent surveillance system. Crosses indicate processed lat-long positions.

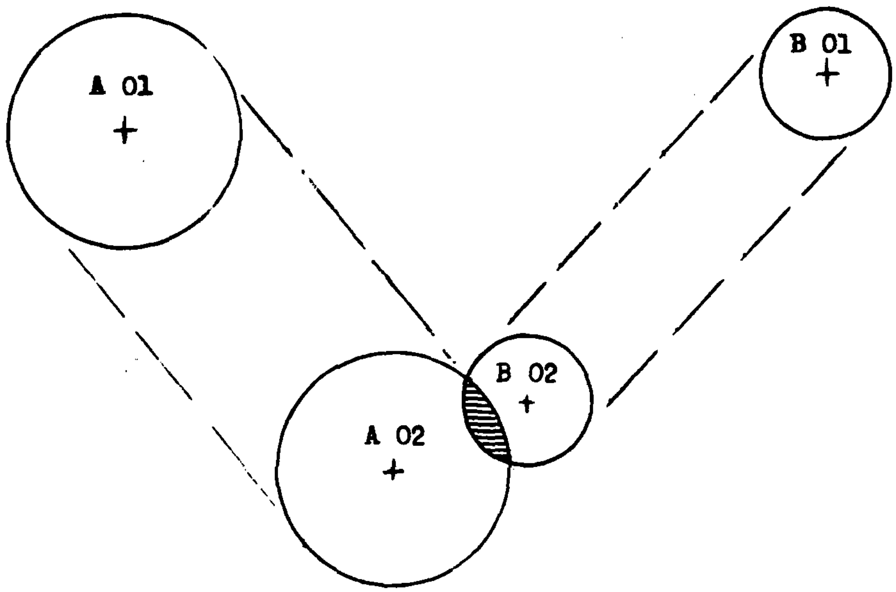


Figure 13. Conflict alert concept, showing initial positions of aircraft A and B at time 01, and predicted positions at time 02.

TABLE 1

(Hypothetical)

Separation in nautical miles between aircraft using various types of surveillance

Combinations	B R I G	LORAN C	OMEGA/ VLF
B R I G	5	7	9 (A)
LORAN C	7	9 (B)	11
OMEGA/ VLF	9	11 (C)	13

Legend:

B R I G -- Beacon, Radar, INS, or GPS

(A) (B) (C) -- Examples (See Text)

BRIG stands for the four most accurate surveillance systems: Beacon, Radar, INS or GPS. In Table 1, Example A shows that one aircraft with INS and another with Omega should be separated at least 9 NM. Example B shows that two aircraft with Loran-C should be separated by at least 9 NM. Example C shows that one aircraft with Loran-C and one with Omega should be separated by at least 11 NM. Such a matrix could be stored within the computer memory; possibly this could do away with much of the complex processing described earlier in this section.

6. VHF Communications Study in the CONUS.

VHF communications equipment to support IFR flying in the NAS has been located primarily along the federal airways. In off-airway areas, and below minimum enroute altitudes along the airways, communications can be marginal or not available at all. This can become a critical problem for aircraft that experience emergencies in which they are losing altitude.

Helicopters conduct much of their flying activities at lower altitudes and in remote areas where federal airways have not been established and hence communications may not be available. While most of this flying is VFR there is an increasing need for IFR service. Furthermore, the increasing trend in IFR helicopters to use RNAV avionics will mean that these helicopters will be capable of IFR flying in areas that transcend the boundaries of the current Federal Airways.

A communications study is needed to determine what augmentation may be required in RCAG facilities in the U.S. to support this type of flying. The study should then be validated by a series of trans-continental flights that establish approximate contour levels at various altitudes where communications services exist and where new services are required. It is likely that the Electromagnetic Compatibility Analysis Center (ECAC) would be most qualified to perform the study.

7. ATC Implication of Alternate Airports for Helicopters

Helicopters have a unique problem with respect to alternate airports. Cruising speeds are seldom over 120 kts, with maximum endurance seldom over 2-1/2 hours. As a result, helicopter pilots must typically select an alternate airport or heliport that is fairly close to the destination airport. Often this means that the alternate is in the same air mass as the destination which further reduces the probability of locating one that has weather at or above the published minima (which were established originally for fixed-wing aircraft).

Many planned helicopter IFR flights are cancelled prior to takeoff because of the inability to find a "legal" alternate airport.

From the standpoint of Helicopter TERPS it appears that different lower minima may be desirable and possible because of the slow approach speed and excellent cockpit visibility characteristics of helicopters. While changes in TERPS cannot appropriately be addressed in this paper, there are ATC implications that can be.

From an ATC standpoint there is a significant implication that comes about from the combination of RNAV capability in the helicopter and the ability to land in almost any flat area that is not much larger than the helicopter's rotor diameter. With this capability, the helicopter has the ability to make a point-in-space approach leading to a landing at many heliports not having radio facilities, or even to flat areas that are not designated as heliports.

When an airplane is prevented from landing at its planned destination and must go to the alternate, the situation becomes one that can very easily turn into an emergency. The alternate is the landing place of last resort. For helicopters, it is less of an emergency because the helicopter can land at many places that are not designated

landing facilities. Typically, weather conditions vary considerbly in short distances and, at any moment, the weather may be considerably better several miles away from an airport than at the airport itself.

The logical conclusion to be drawn from this discussion is that if the weather information is known (even if this is only in the cockpit), if navigation service is available, and if communications are available, there is nothing to prevent an approach to a landing site of opportunity. Furthermore, this decision could be made in flight or it could be made during flight planning.

An analysis is needed to investigate this concept and develop the associated ATC procedures. Once these procedures are identified they could be evaluated in the Northeast Corridor.

8. Wake Vortex Separation

Very large separations are presently required behind large (particularly wide-bodied) aircraft to guard against vortex upsets. Because airport capacity is inversely proportional to the average time interval between aircraft operations, these large separations reduce airport capacity and increase traffic delays.

Such effects are even more pronounced when helicopters have to follow behind large fixed wing aircraft. Due to their slower speed, what starts out as a large separation interval becomes much larger yet before the helicopter reaches the airport.

There is a need to determine whether the vortex separation standards published in ATC Handbook 7110.65B can be safely reduced for helicopters flying behind fixed-wing aircraft; and if so, to what values under what conditions.

There is considerable evidence to indicate that helicopters are less sensitive than fixed wing aircraft of the same weight category, to the vortices generated by other fixed-wing aircraft.

This evidence includes the results of tests made by NASA in 1975-76, in which a specially instrumented Bell UH-1H helicopter was climbed into, and turned into, the wake of a C-54 aircraft at varying distances from 6 NM to 3/8 NM. The UH-1H was flown at an approach speed of 60 kt., which corresponded closely to its minimum-drag or maximum-climb speed.

These results indicated that (1) the maximum structural loads on the rotor blades were nominal, and less than those encountered in a moderate

turn in the test helicopter; (2) the only attitude changes were small excursions in the yaw angle; (3) tail rotor flapping was within safe limits; and (4) the helicopter was surprisingly insensitive to separation distance behind the C-54, between 6 NM and 3/8 NM. Comparison of flight tests with analytical simulation of the encounters showed that the simulation could predict trends and magnitudes of the wake vortex effects of the helicopter.

Although it was hoped that NASA could continue this program, with larger generating aircraft, a wider range of helicopters (including fixed rotor, articulating rotor, and teetering rotor types), higher penetrating airspeeds, and other penetration modes (including transverse penetrations), the program was dropped when NASA moved its helicopter R&D from Langley to Ames.

It is realized that the expansion of the test matrix to include all the variables above would be an expensive, long-range project. With the growing knowledge of vortex flow fields and rotor dynamics, it may be possible to simulate all the encounter conditions first, and reduce the number of actual flight penetrations to the minimum necessary to verify or disprove the simulation results. It would be desirable that the test envelopes overlap some of the work reported above, in order to test the consistency of the results, in drawing up safe separation standards useable in the air traffic control system.

The knowledge gained could be very useful in safely increasing airport capacity by reducing unnecessary aircraft delays and fuel consumption.

Helicopters themselves generate very turbulent wakes which can affect other aircraft. Research is desirable to determine realistic separation criteria which should be used between helicopters and following light fixed-wing aircraft on the same flight path. Flight tests should cover a suitable range of helicopter weights, disc loadings, and airspeeds, for single-rotor and twin-rotor helicopters.

Because of the overlapping of blade paths, it is possible that the extremely turbulent infrastructure of a helicopter wake may generate enough internal shearing effects to cause early dissipation of the vortices. It is suggested that the test helicopters be fitted with smoke generators or possibly agricultural spray rigs to provide a means of marking the location of the vortices, and that the light aircraft be equipped with accelerometers and strain guages for recording penetration encounters at different distances behine the helicopters, using the different penetration modes shown in Figure 14. This work should be accomplished either by NASA or by the FAA Technical Center.

A related matter which needs investigation is the establishment of realistic separation criteria between hover-taxiing helicopters and parked aircraft. This might be accomplished by a simple research project in which various types of helicopters are hover-taxied at various speeds down a marked lane on the airport surface; across this lane a transverse row of anemometers would be installed as shown in Figure 15. Simultaneous recordings would be made by all sensors and by a clock and a videotape camera, to determine the lateral spread, drift, and duration

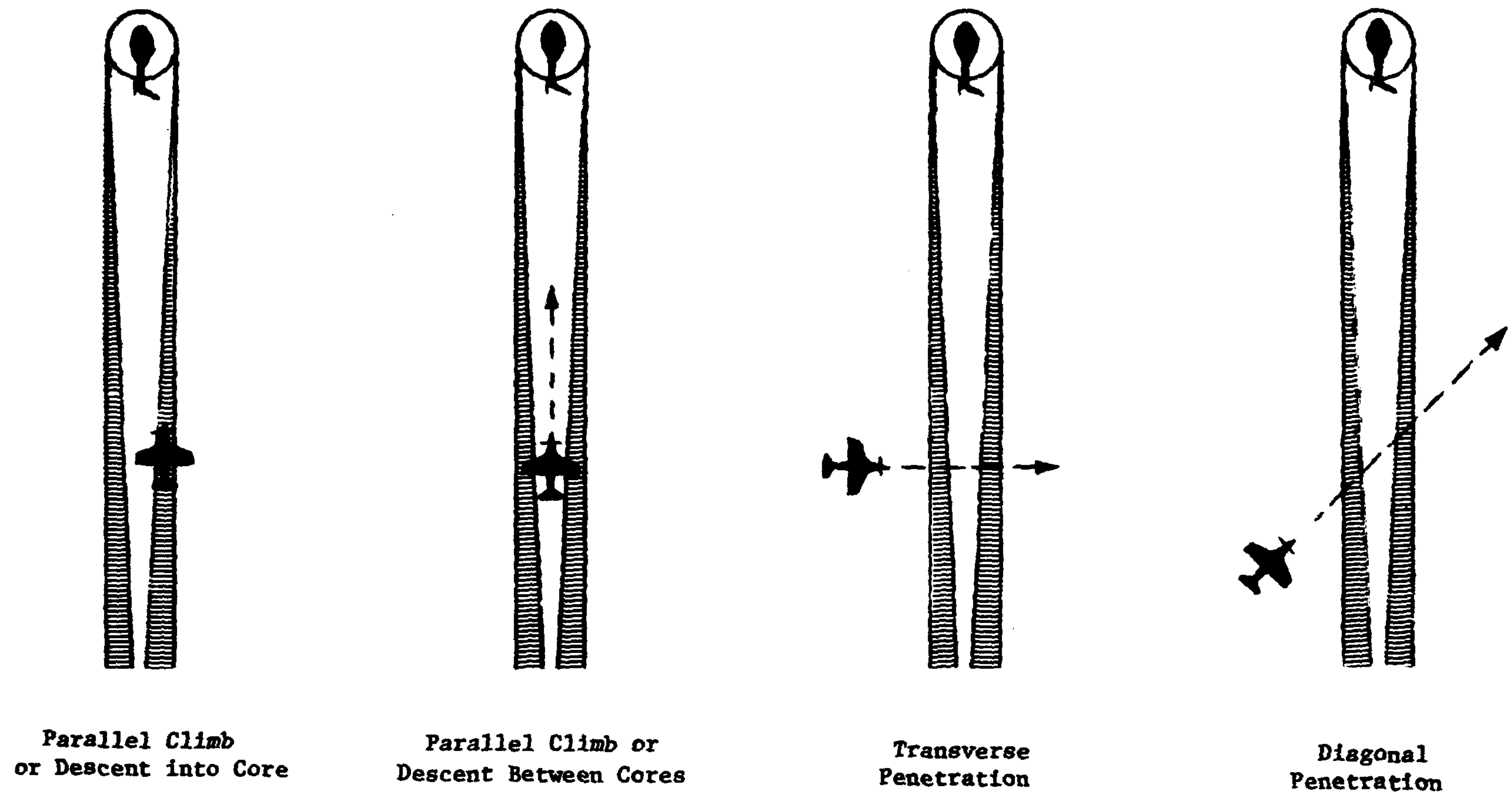


Figure 14 Lightplane Penetration Modes into Helicopter Vortices

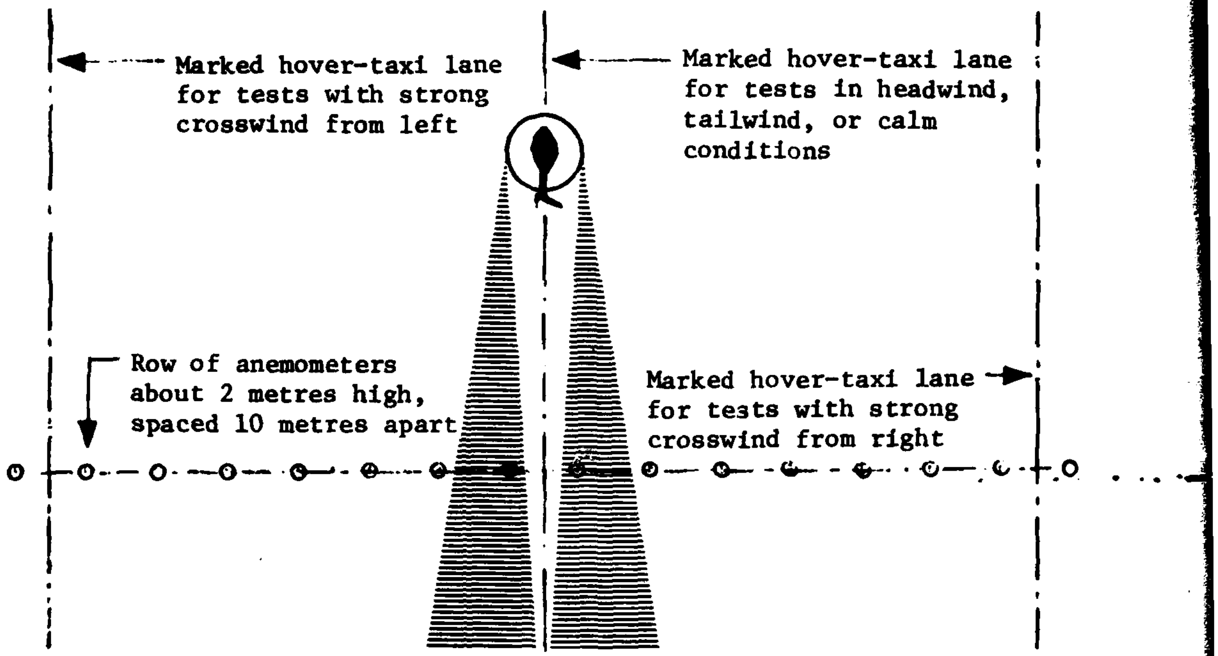


Figure 15. Hover-taxi Wake Measurement Test Layout

Note: Offside camera not shown

of turbulence which might be hazardous to light aircraft parked near a hover-taxi path. Tests could be made by a variety of helicopters at various taxiing speeds, in a wide variety of wind conditions. If available, a doppler radar could be mounted on the taxi path to record precise measurements of ground speed.

It is recommended that these hover-taxi tests be made by the FAA Technical Center, or by NASA-Langley or NASA-Ames.